

Continuous Renal Replacement Therapy

Basic Therapy Principles

Continuous Renal Replacement Therapy (CRRT)

Is an extracorporeal blood purification therapy intended to substitute for impaired renal function over an extended period of time and applied for or aimed at being applied for 24 hours a day.

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Bellomo R., Ronco C., Mehta R, *Nomenclature for Continuous Renal Replacement Therapies*, AJKD, Vol 28, No. 5, Suppl 3, November 1996

CRRT Goals

- Mimic the functions and physiology of the native organ
- Qualitative and quantitative blood purification
- Restore and maintain of homeostasis
- Avoid complications and good clinical tolerance
- Provide conditions favoring recovery of renal function

Requirements for CRRT

- **CRRT requires:**
 - **A central double-lumen veno-venous hemodialysis catheter**
 - **An extracorporeal circuit and a hemofilter**
 - **A blood pump and a effluent pump.**
 - **With specific CRRT therapies dialysate and/or replacement pumps are required.**

CRRT Modalities

- **SCUF**- Slow Continuous Ultrafiltration
 - Ultrafiltration
- **CVVH**- Continuous Veno-Venous Hemofiltration
 - Convection
- **CVVHD**- Continuous Veno-Venous Hemodialysis
 - Diffusion
- **CVVHDF**- Continuous Veno-Venous Hemodiafiltration
 - Diffusion and Convection

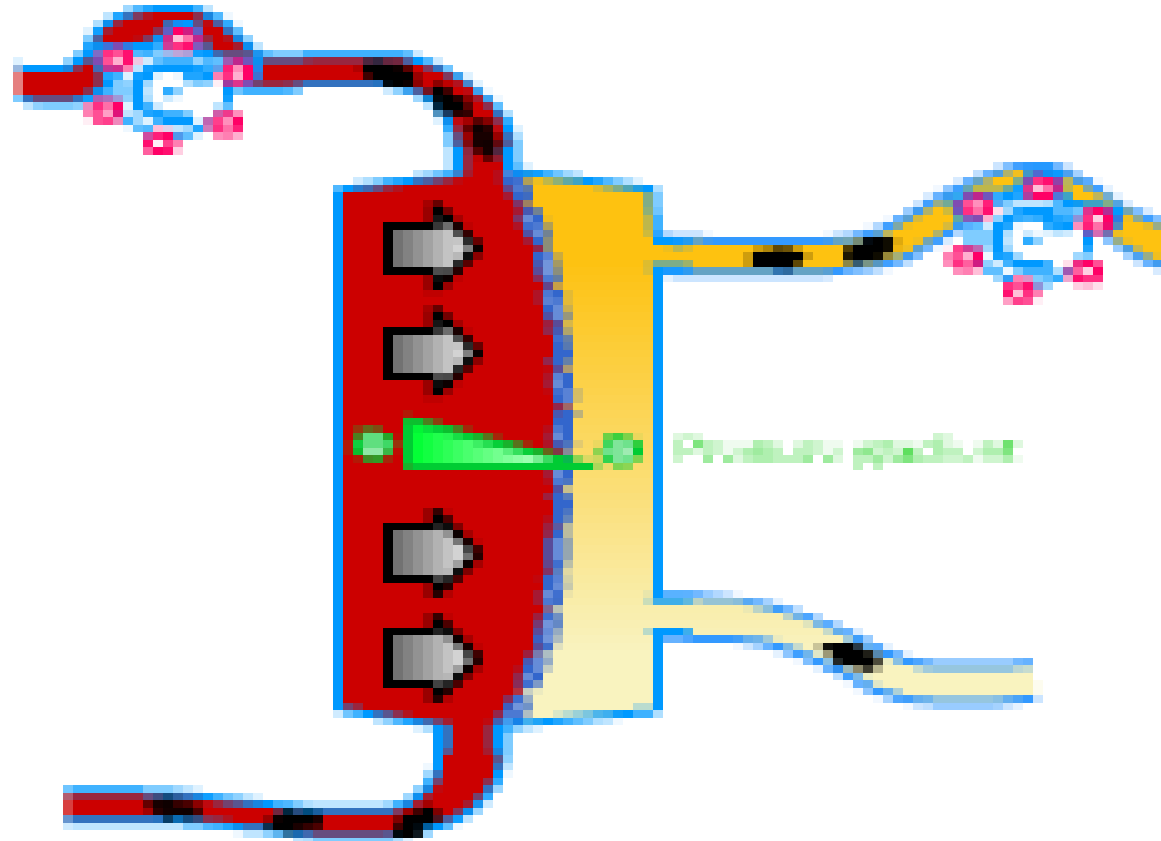
SCUF-Ultrafiltration

- **Slow continuous ultrafiltration:**
 - Requires a blood and an effluent pump.
 - No dialysate or replacement solution.
 - Fluid removal up to 2 liters/hr can be achieved.
- **Primary Goal**
 - Safe management of fluid removal
 - Large fluid removal via ultrafiltration

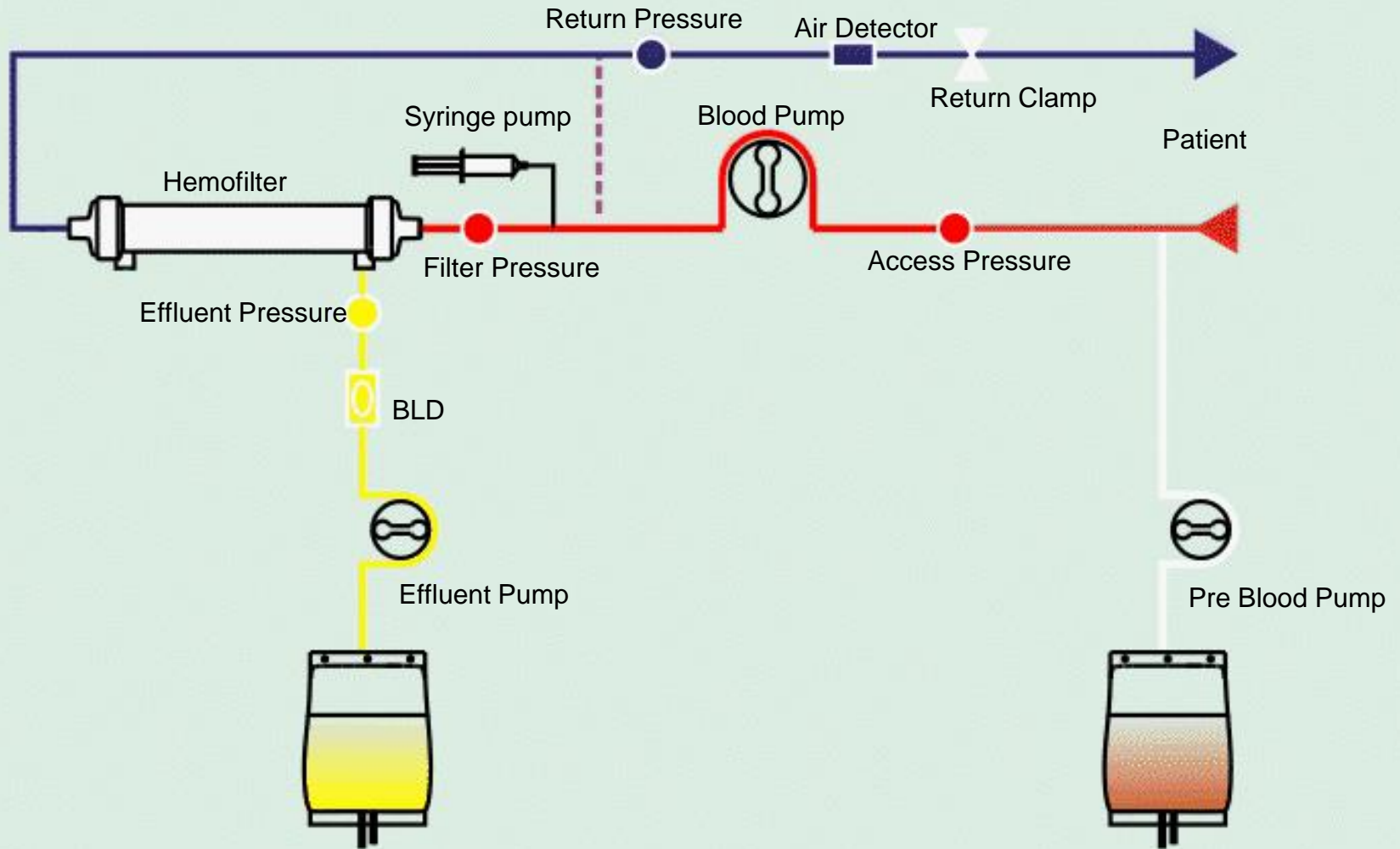
Transport mechanism: Ultrafiltration

- **The movement of fluid through a semi-permeable membrane driven by a pressure gradient (hydrostatic pressure). The effluent pump forces plasma water and solutes across the membrane in the filter.**
- **This transport mechanism is used in SCUF, CVVH, CVVHD, and CVVHDF.**

ULTRAFILTRATION



SCUF



CVVH-Convection

- **Continuous veno-venous hemofiltration**
 - **Requires blood, effluent and replacement pumps.**
 - **Dialysate is not required.**
 - **Plasma water and solutes are removed by convection and ultrafiltration.**

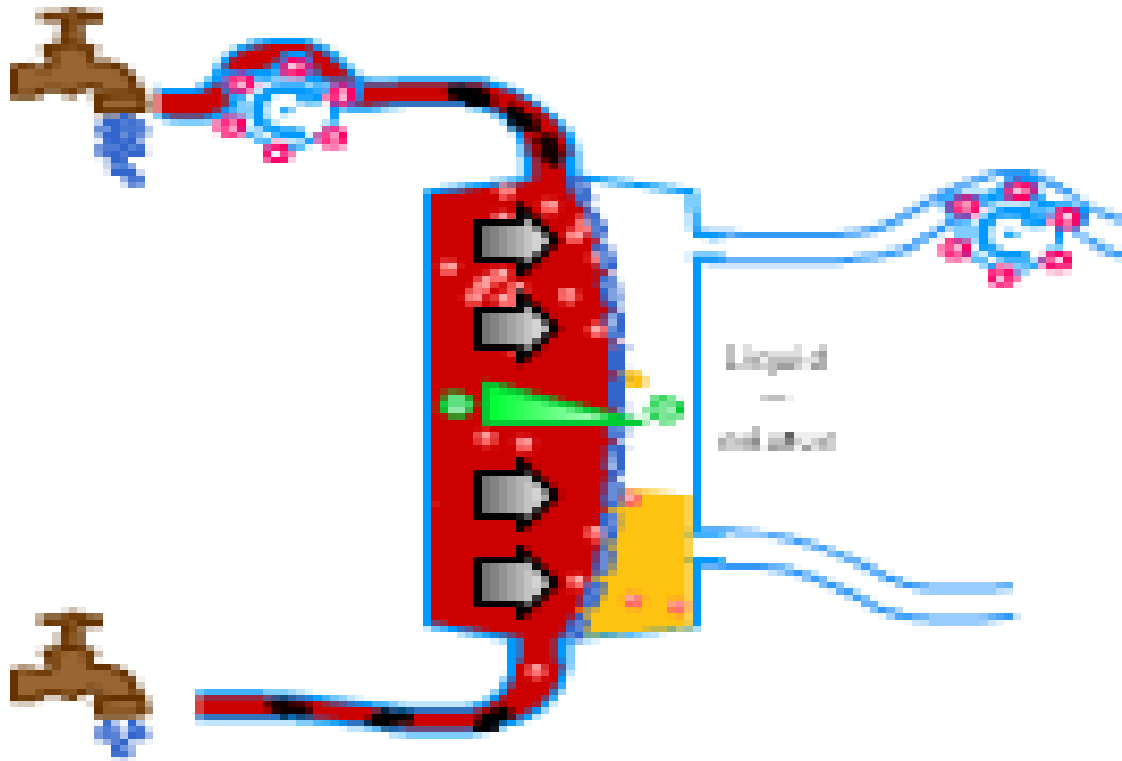
Transport Mechanism: Convection

- **Removal of solutes, especially middle and large molecules, by convection of relatively large volumes of fluid and simultaneous.**
- **This transport mechanism is used:**
 - **CVVH**
 - **CVVHDF**

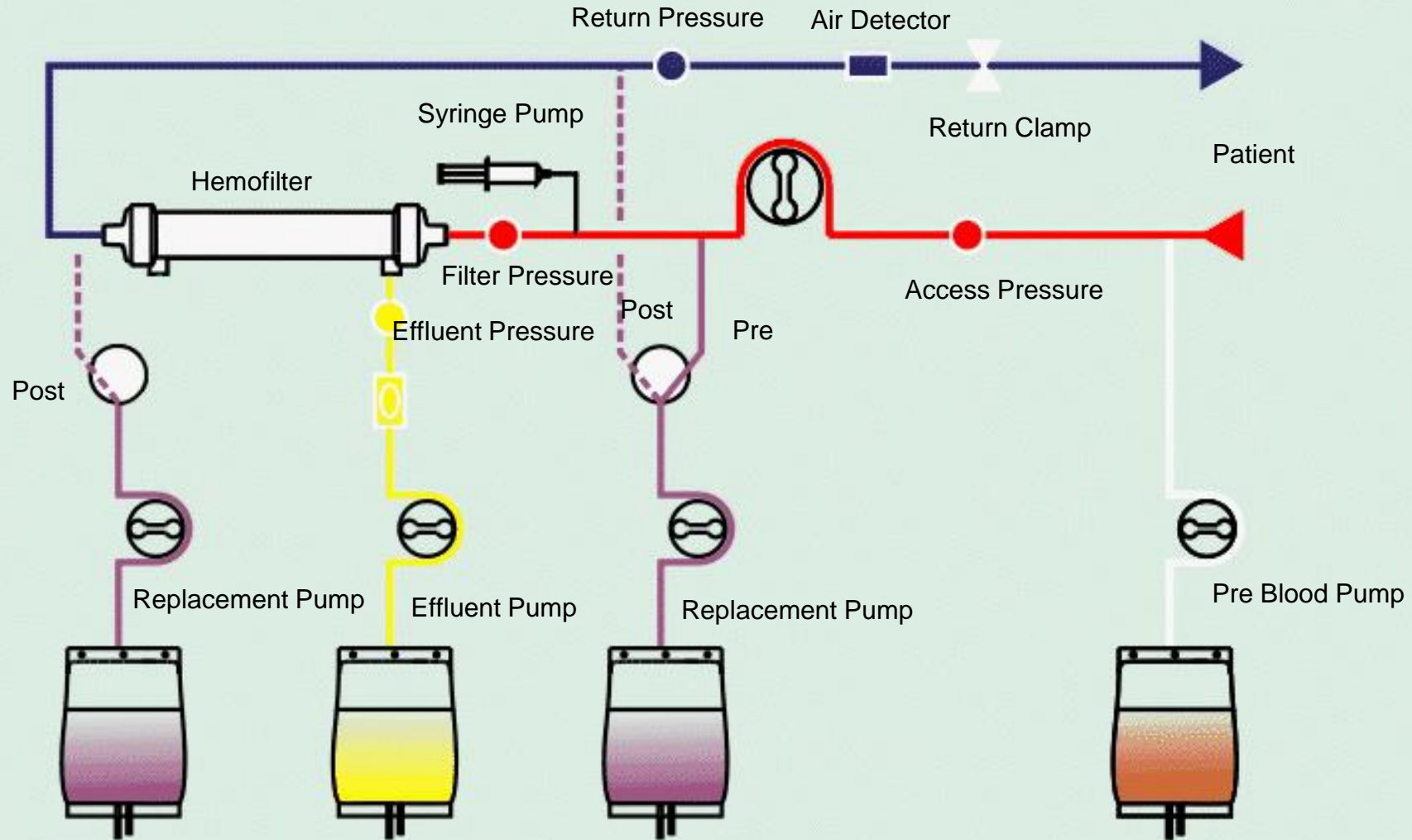
Replacement Fluids

- **Physician Rx and adjusted based on pt. clinical need.**
- **Sterile replacement solutions may be:**
 - **Bicarbonate-based or Lactate-based solutions**
 - **Electrolyte solutions**
 - **Must be sterile and labeled for IV Use**
 - **Higher rates increase convective clearances**
 - **You are what you replace**

CONVECTION



CVVH



CVVHD-Diffusion

- **Continuous veno-venous hemodialysis**
 - **Requires the use of blood, effluent and dialysis pumps.**
 - **Replacement solution is not required.**
 - **Plasma water and solutes are removed by diffusion and ultrafiltration.**

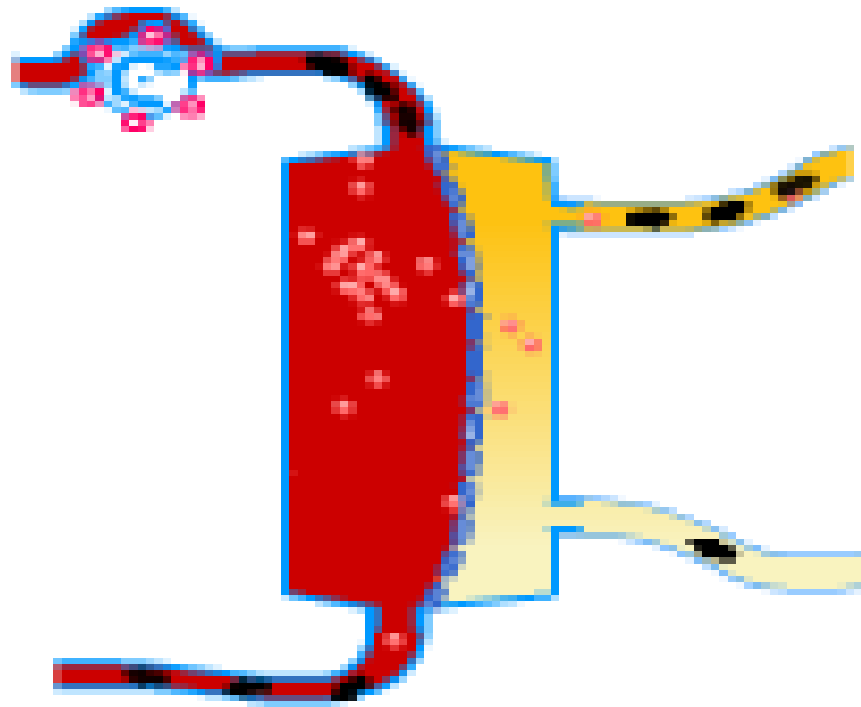
Transport Mechanisms: Diffusion

- Removal of small molecules by diffusion through the addition of dialysate to the fluid side of the filter.
- Dialysate is used to create a concentration gradient across a semi permeable membrane
- Dialysis uses a semi permeable membrane for selected diffusion
- This transport mechanism is used in:
 - CVVHD
 - CVVHDF

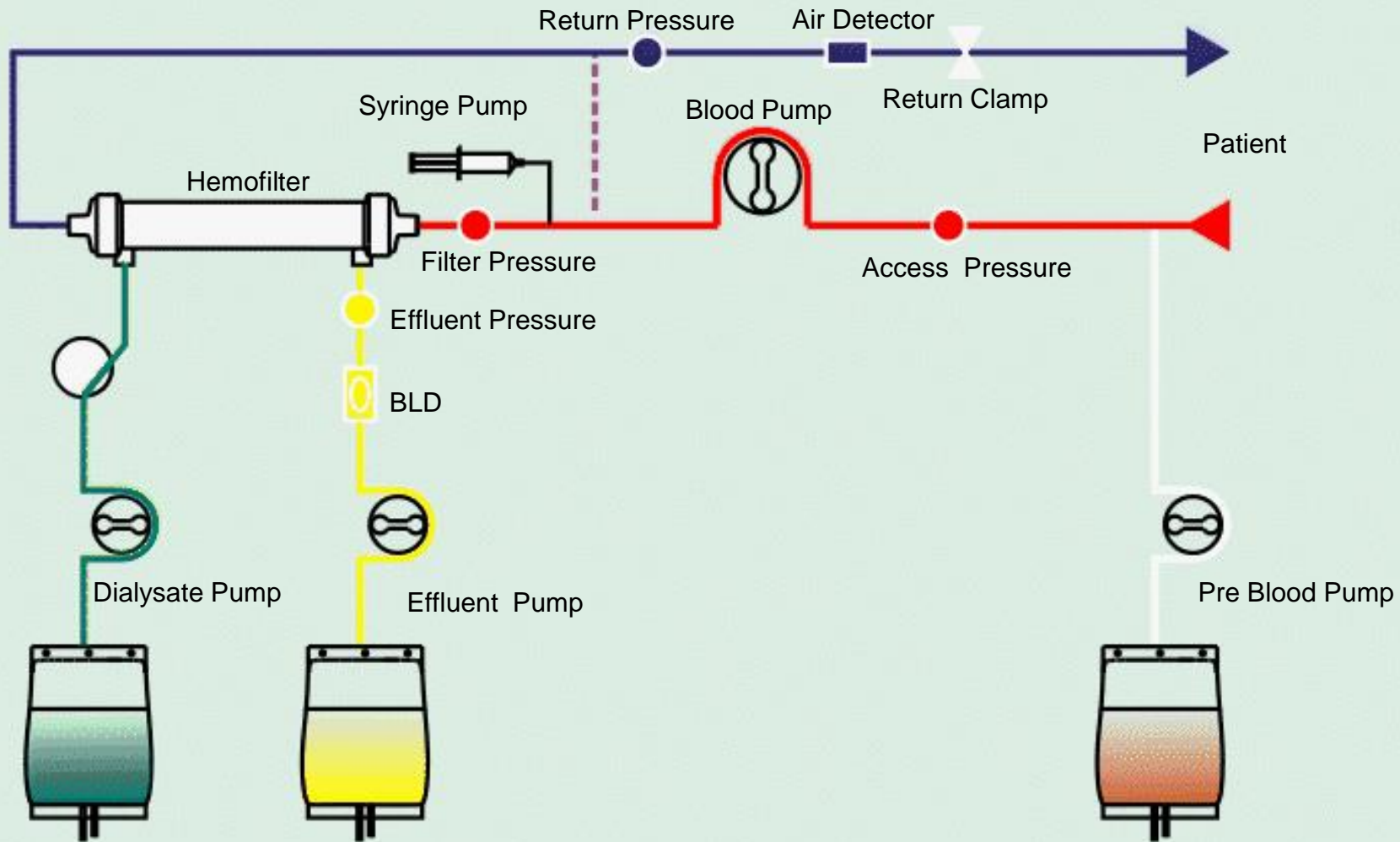
Dialysate Solutions

- **Through diffusion, dialysate corrects underlying metabolic problems**
- **Dialysate is dependent on buffering agent, electrolytes, and glucose**
- **Dialysate formulas should reflect normal plasma values to achieve homeostasis**

DIFFUSION



CVVHD



Bicarbonate Based Solution

- **Bicarbonate based solutions are physiologic and replace lost bicarbonate immediately.**
- **Effective tool to correct acidosis**
 - **Concentration of 30-35mEq/L corrects acidosis in 24 to 48 hours.**

Bicarbonate Based Solution

- **Preferred buffer for patients with compromised liver function.**
- **Mean arterial pressure remains stable**
- **Superior buffer in normalizing acidosis without the risk of alkalosis**
- **Improved hemodynamic stability, and fewer cardiovascular events.**

PrismaSate Solution

	Plasma	PrismaSate BK0/3.5	PrismaSate BGK2/0
Calcium Ca²⁺ (mEq/L)	4.3 - 5.3	3.5	0
Magnesium Mg²⁺ (mEq/L)	1.5 - 2.5	1.0	1.0
Sodium Na⁺ (mEq/L)	135 - 145	140	140
Potassium K⁺ (mEq/L)	3.5 - 5.0	0	2.0
Chloride Cl⁻ (mEq/L)	95 - 108	109.5	108
Lactate (mEq/L)	0.5 - 2.0	3	3
Bicarbonate HCO₃⁻ (mEq/L)	22 - 26	32	32
Glucose (mg/dL)	65 - 110	0	110
Osmolarity (mOsm/L)	280 - 300	287	292
pH	7.35 - 7.45	~ 7.40	~ 7.40

Lactate-based Solution

- Metabolized into bicarbonate providing it's under normal conditions.
- Lactate is converted in the liver on a 1:1 basis to bicarbonate and can sufficiently correct acidemia.

Lactate Based Solution

- **Non physiologic pH value of 5.4**
- **Is a powerful peripheral vasodilator**
- **Further acidemia for patients in:**
 - **Hypoxia**
 - **Liver impairment**
 - **Pre-existing lactic acidemia can result in worsening of lactic acidemia**

CVVHDF

- **Continuous veno-venous hemodiafiltration**
 - **Requires the use of a blood, effluent, dialysate and replacement pumps.**
 - **Both dialysate and replacement solutions are used.**
 - **Plasma water and solutes are removed by diffusion, convection and ultrafiltration.**

Transport Mechanisms: **Diffusion and Convection**

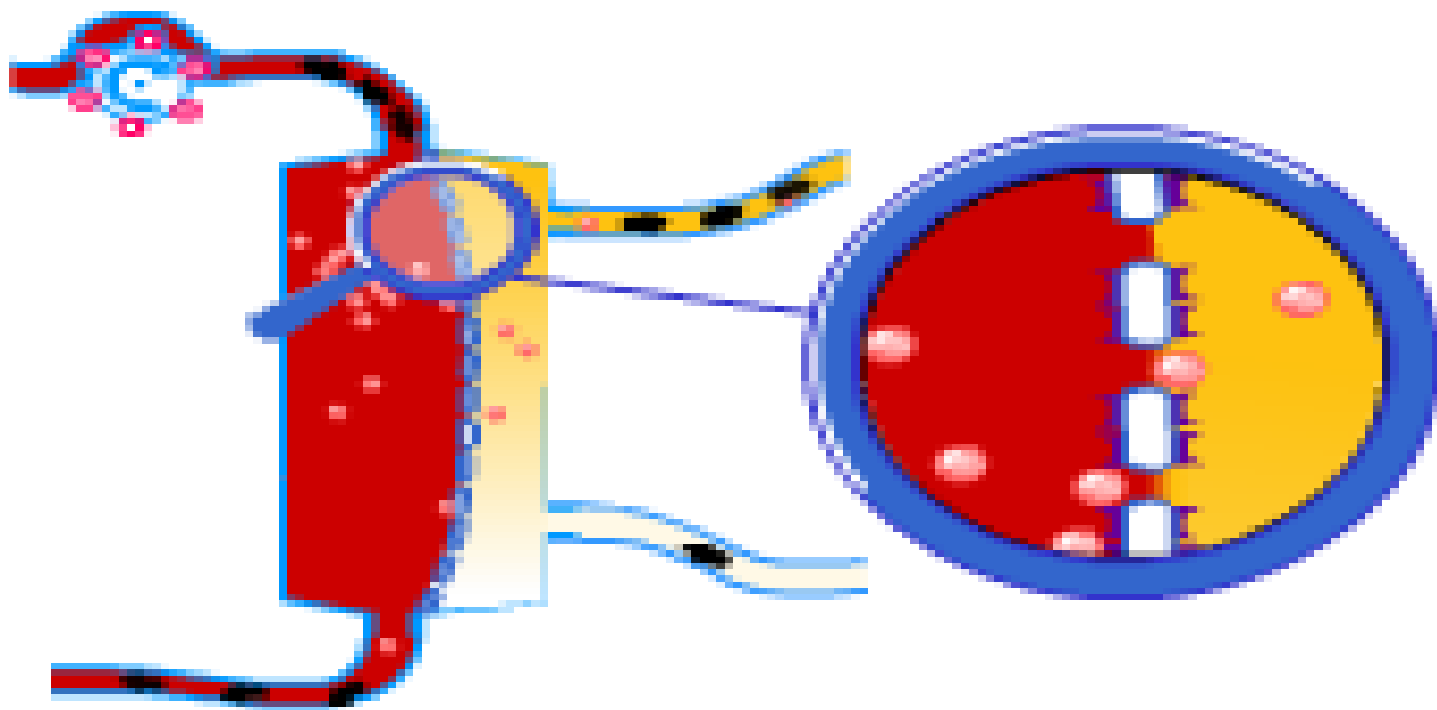
- Removal of small molecules by diffusion through the addition of dialysate solution.
- Removal of middle to large molecules by convection through the addition of replacement solution.
- This transport mechanism is used in:
 - CVVHDF

CRRT Transport Mechanisms

Adsorption

- Molecular adherence to the surface or interior of the membrane
- This mechanism is used in:
 - **SCUF**
 - **CVVH**
 - **CVVHD or CVVHD with ultrafiltration**
 - **CVVHDF**

ADSORPTION

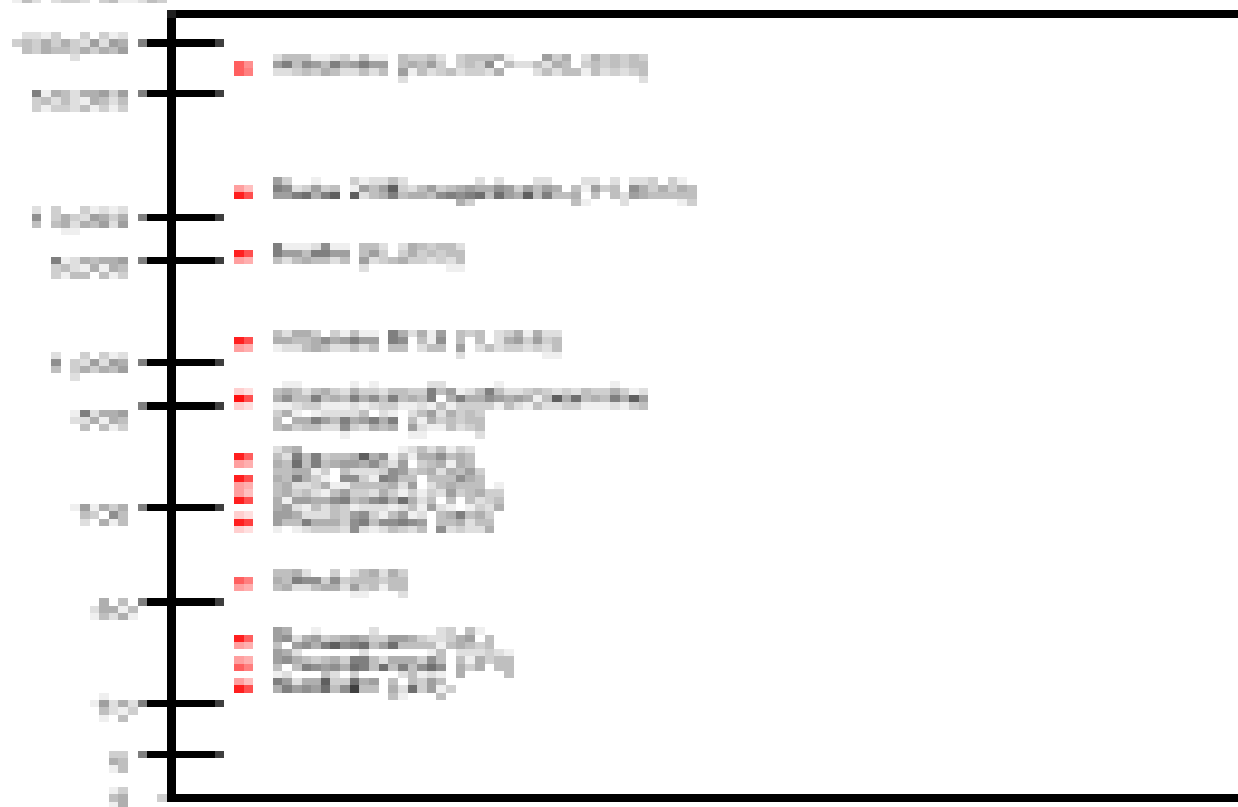


Principles of CRRT clearance

- CRRT clearance of solute is dependent on the following:
 - The molecule size of the solute
 - The pore size of the semi-permeable membrane
- The higher the ultrafiltration rate (UFR), the greater the solute clearance.

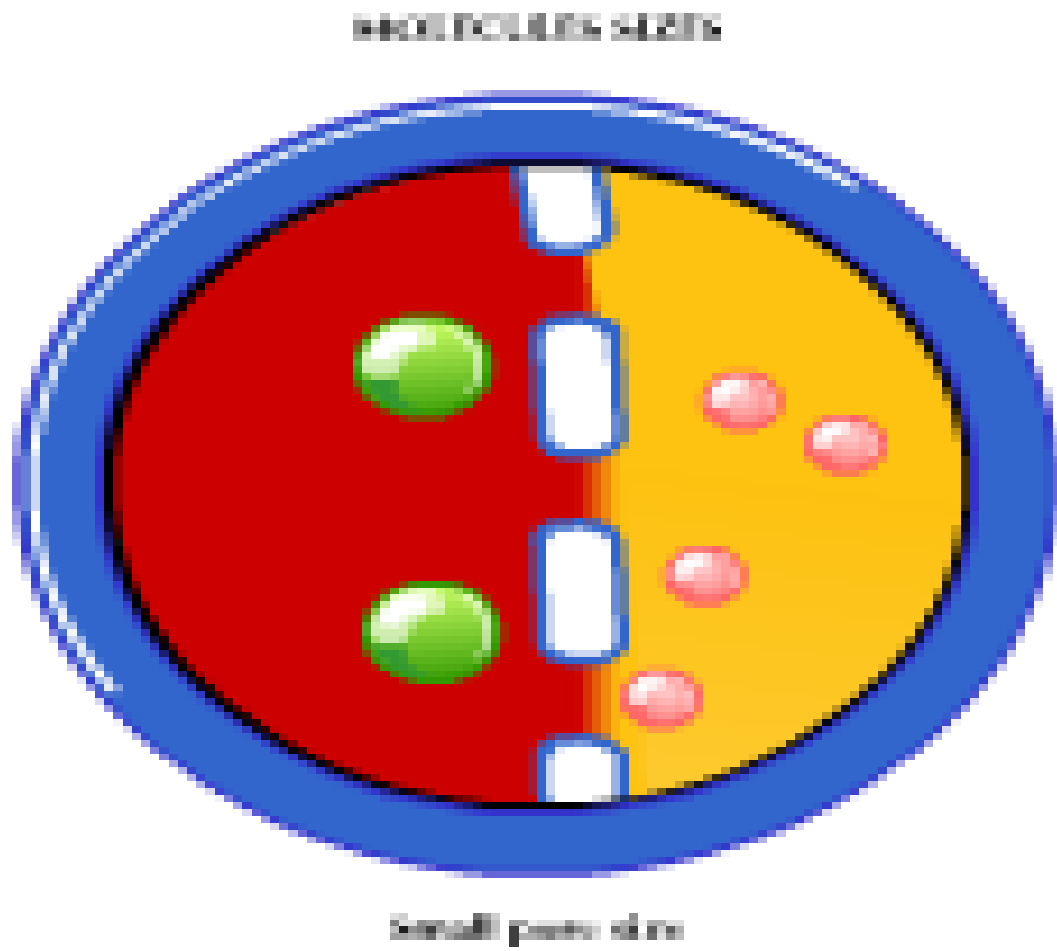
1. **Introduction**

1. *Journal of Management Studies*, 1996, 33, 1, 1-14.
 2. *Journal of Management Studies*, 1996, 33, 2, 1-14.

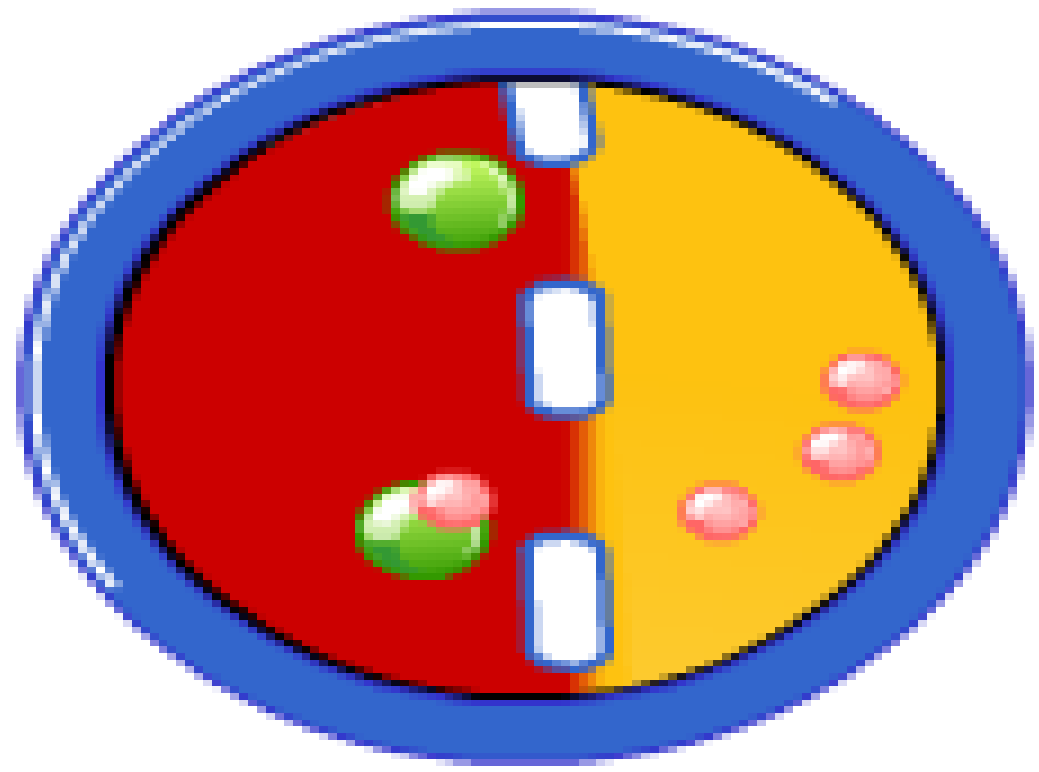


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BACK DOUBLING SIZES



Large pores slow

Principles of CRRT clearance

- Small molecules easily pass through a membrane driven by diffusion and convection.
- Middle and large size molecules are cleared primarily by convection.
- Semi-permeable membrane remove solutes with a molecular weight of up to 50,000 Daltons.
- Plasma proteins or substances highly protein—bound will not be cleared.

Principles of CRRT clearance

- **Sieving Coefficient**
 - The ability of a substance to pass through a membrane from the blood compartment of the hemofilter to the fluid compartment.
 - A sieving coefficient of 1 will allow free passage of a substance; but at a coefficient of 0, the substance is unable to pass.
 - .94 Na⁺
 - 1.0 K⁺
 - 1.0 Cr
 - 0 albumin will not pass

Vascular Access

- A veno-venous double lumen hemodialysis catheter or two single lumen venous hemodialysis catheters may be used.

Access Location

- **Internal Jugular Vein**
 - **Primary site of choice due to lower associated risk of complication and simplicity of catheter insertion.**
- **Femoral Vein**
 - **Patient immobilized, the femoral vein is optimal and constitutes the easiest site for insertion.**
- **Subclavin Vein**
 - **The least preferred site given its higher risk of pneumo/hemothorax and its association with central venous stenosis.**

Choosing the right catheter

- **The length of the catheter chosen will depend upon the site used**
 - **Size of the catheter is important in the pediatric population.**
- **The following are suggested guidelines for the different sites:**
 - **RIJ= 15 cm French**
 - **LIJ= 20 cm French**
 - **Femoral= 25 cm French**

Membrane types and characteristics

- **Hemofilter membrane are composed of:**
 - High flux material
 - Synthetic/biocompatible material
- **Structural design is characterized by:**
 - High fluid removal
 - Molecular cut-off weight of 30,000-50,000 Daltons.

Semi-permeable Membrane

- **The semi-permeable membrane provides:**
 - **An interface between the blood and dialysate compartment.**
- **Biocompatibility minimizes:**
 - **Severe patient reactions**
 - **Decreases the complement activation**

Complications

- **Vascular access**
 - **Vascular spasm(initial BFR too high)**
 - **Movement of catheter against vessel wall**
 - **Improper length of hemodialysis catheter inserted**
- **Fluid volume deficit**
 - **Excessive fluid removal without appropriate fluid replenishment**

Complications

- **Hypotension**
 - **Intravascular volume depletion**
 - **Underlying cardiac dysfunction**
- **Electrolyte imbalances**
 - **High ultrafiltration rates (high clearance)**
 - **Inadequate replenishment of electrolytes by intravenous infusion,**
 - **Inadequate replenishment of bicarbonate loss during CRRT**

Complications

- **Acid/base imbalance**
 - **Renal dysfunction**
 - **Respiratory compromise**
- **Blood loss**
 - **Ineffective anticoagulation therapy**
 - **Clotting of hemofilter**
 - **Inadvertent disconnection in the CRRT system**
 - **Hemorrhage due to over-anticoagulation**
 - **Blood filter leaks**

Complications

- **Air embolus**
 - **Leaks or faulty connections in tubing**
 - **Line separation.**
- **Cardiac arrest**
 - **Hypotension/hypertension**
 - **Hemolysis**
 - **Air embolism**
 - **Circulatory overload**
 - **Arrhythmias**

Clinical Conditions to Consider

ARF and need for fluid management related to:

- **SIRS**
- **Unstable on IHD**
- **Organ transplants**
- **CHF /volume overload**
- **Post CV surgery**
- **Post trauma patients**
- **Severe Burns**

Fluid Management in CRRT

Goal of Fluid Management

- **“The patient will achieve and maintain fluid volume balance within planned or anticipated goals”
(ANNA Standards of Clinical Practice for Continuous Renal Replacement Therapy)”**

Considerations

- **Intakes and outputs (I&O)**

I & O Formula

Net fluid removal hourly (physician order)

+

Nonprisma intake (IV, TPN, etc.)

-

Nonprisma output (urine, etc.)

=

Patient Fluid Removal Rate (set in prisma)

Hypothermia in CRRT

Causes

- Patient's blood in extracorporeal circuit at room temperature
- Administration of large volumes of room temperature fluids (replacement and dialysate)

Signs and Symptoms

- Hemodynamic instability
- Chilling, shivering
- Skin pallor, coolness and cyanosis

Hypothermia

Treatment measures

- **Warming blankets**
- **Prismatherm™ II Blood Warmer**
- **Prismaflo® Blood Warmer**

Initiation of Therapy

- **Assess and record the patient's vital signs and hemodynamic parameters prior to initiation of therapy.**
- **Review physician orders and lab data**
- **Prepare vascular access using unit protocol.**
- **Set fluid removal, dialysate and replacement solution flow rates as prescribed.**
- **Administer anticoagulant and initiate infusion if applicable.**
- **Document patient's hemodynamic stability with initiation of therapy.**

Intratherapy Monitoring

The critical care nurse must continuously monitor the following parameters during CRRT

- Blood pressure
- Patency of circuit
- Hemodynamic stability
- Level of consciousness
- Acid/base balance
- Electrolyte balance
- Hematological status
- Infection
- Nutritional status
- Air embolus
- Blood flow rate
- Ultrafiltration flow rate
- Dialysate/replacement flow rate
- Alarms and responses
- Color of ultrafiltrate/filter blood leak
- Color of CRRT circuit

Termination of Therapy

- **The decision to terminate CRRT is made by the nephrologist or an intensivist based on the patient's renal recovery or the patient's status-recovery or decision of the patient and family.**
 - **Extracorporeal circuit will be discontinued as per established protocol.**
 - **Vascular access care administered as per unit protocol**

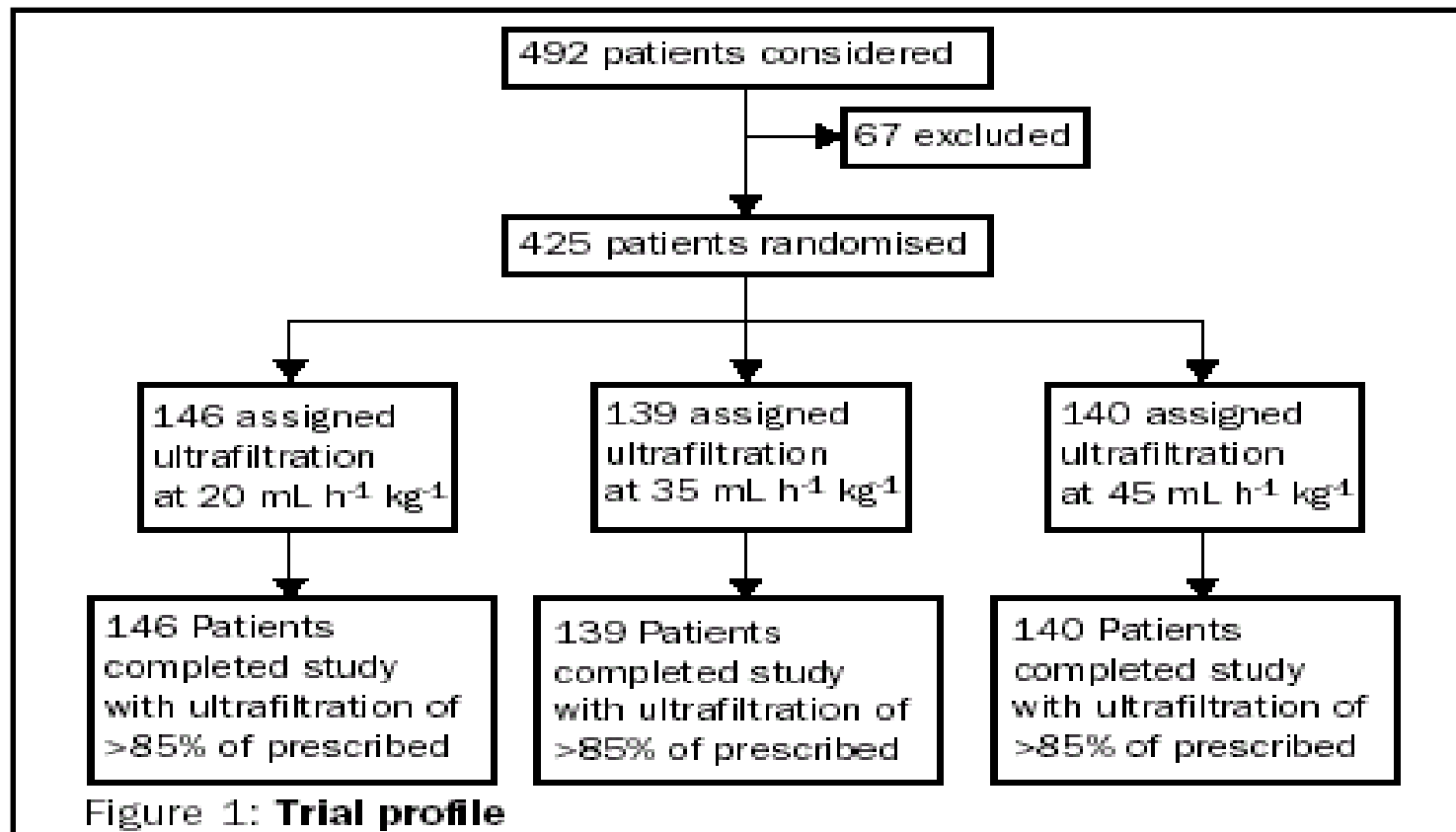
Current Research

FAQs

How much replacement and dialysate do you use?

Ronco's research

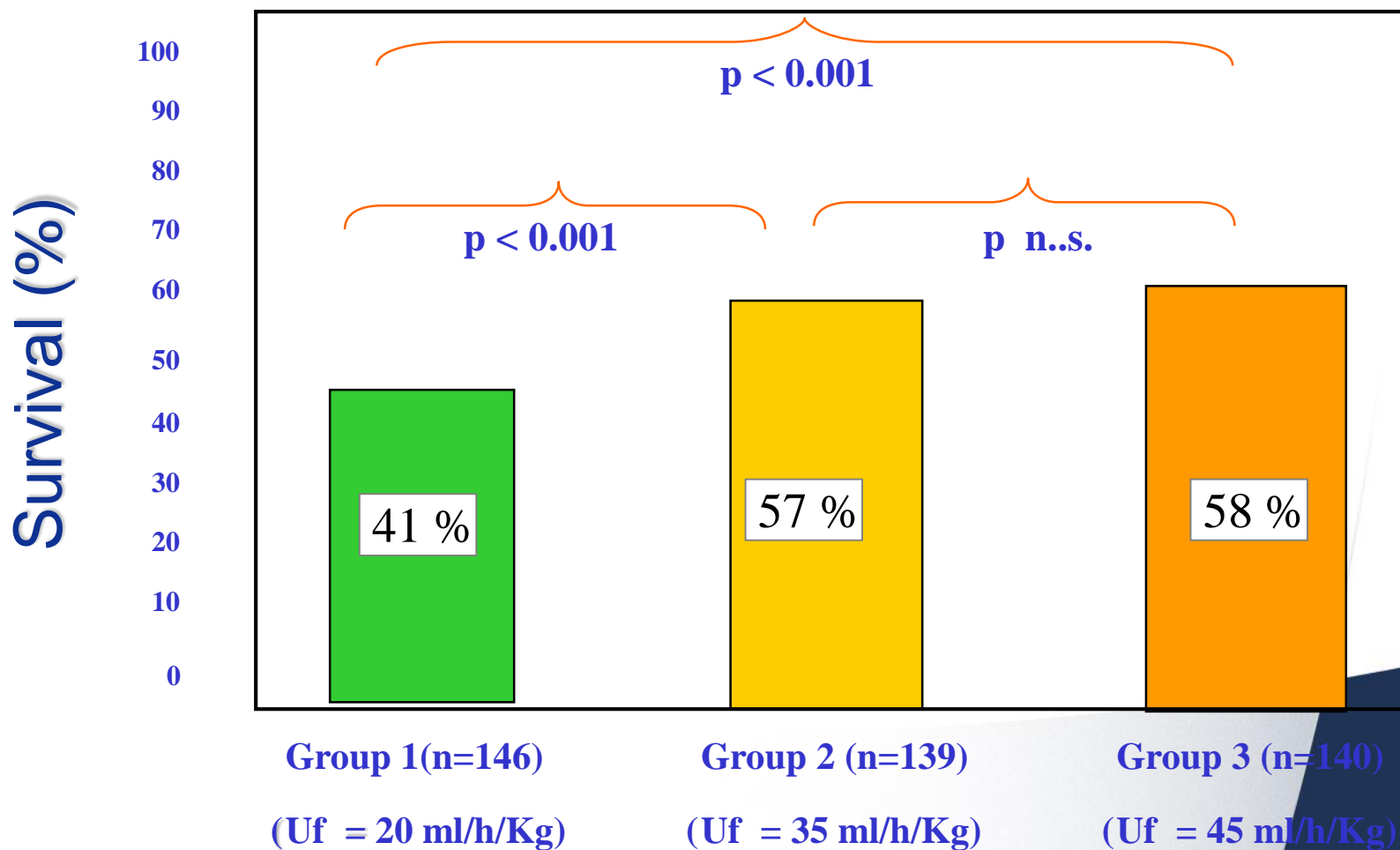
Prospective study on 425 patients - 3 groups:



Study:

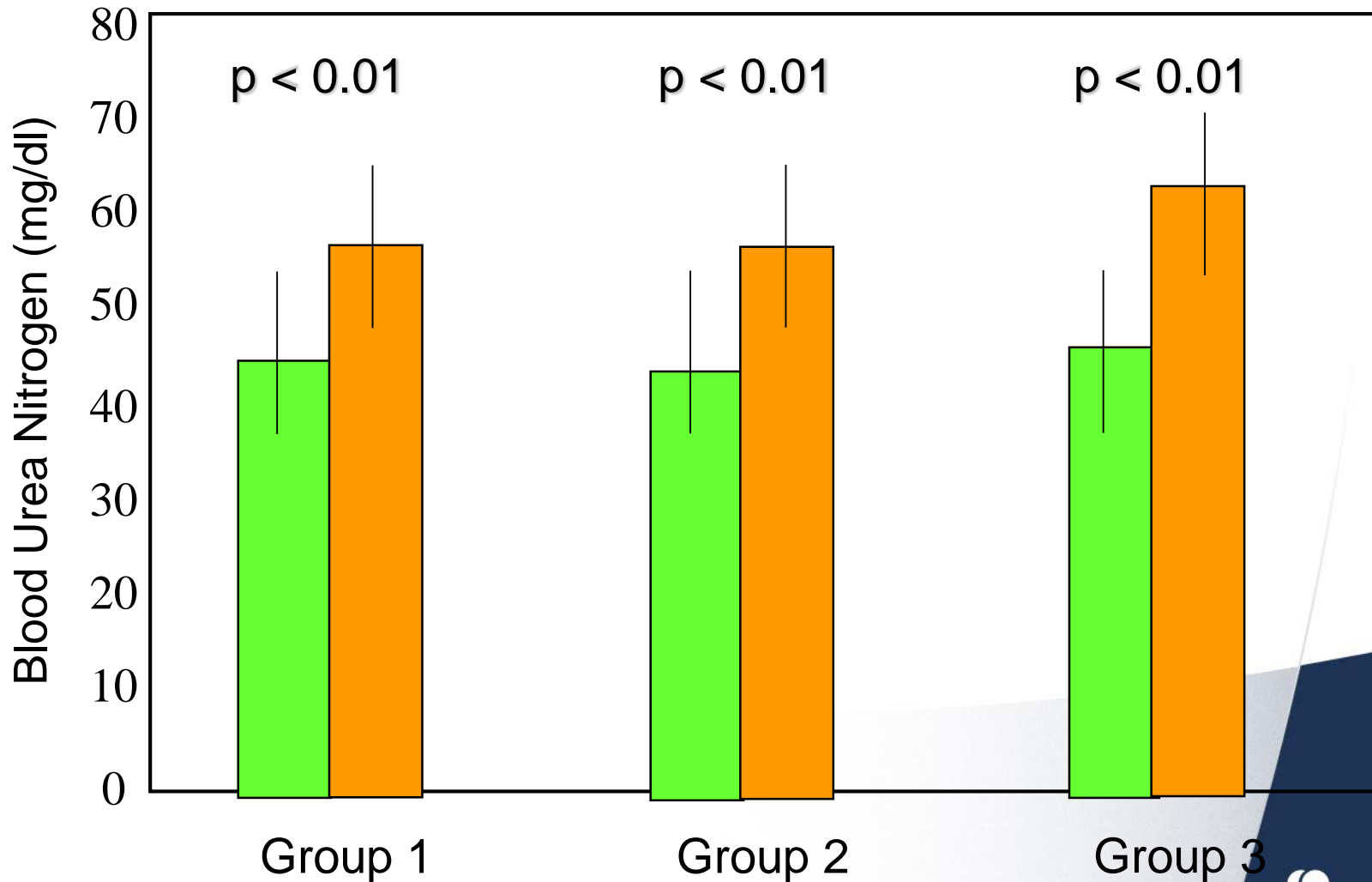
- survival after 15 days of HF stop
- recovery of renal function

Effects of different doses in CVVH on outcome of ARF - *Ronco & Bellomo study. Lancet . july 00*



Effect of BUN at CVVH Initiation on Survival

Survivors Non Survivors



RIFLE Criteria

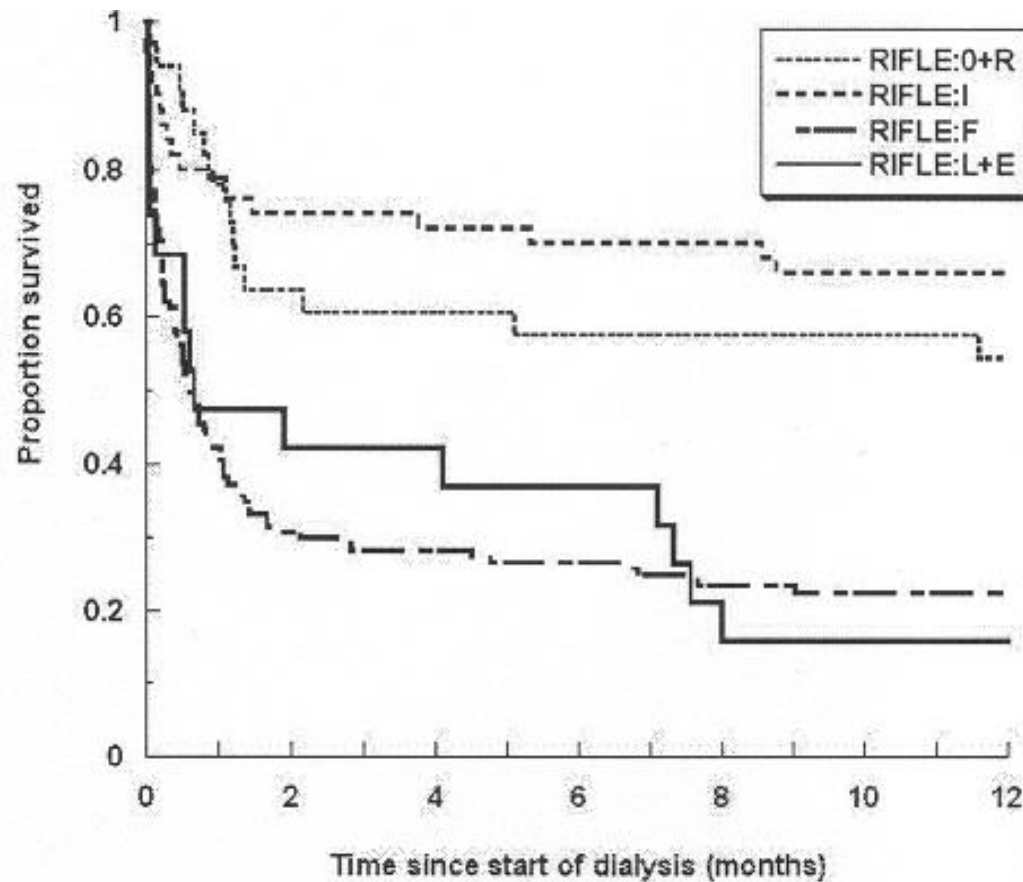
The preliminary results of the second ADQI consensus conference (May 2002, Vicenza, Italy) on research in Acute Renal Failure will be published in the December issue of **Current Opinion in Critical Care**. Final results will be submitted for publication in 2003. This publication will include the first consensus criteria for ARF. The **RIFLE system** uses either GFR criteria

RIFLE Criteria for Acute Renal Dysfunction

	GFR Criteria*	Urine Output Criteria	
Risk	Increased creatinine x1.5 or GFR decrease > 25%	UO < .5ml/kg/h x 6 hr	High Sensitivity
Injury	Increased creatinine x2 or GFR decrease > 50%	UO < .5ml/kg/h x 12 hr	
Failure	Increase creatinine x3 or GFR decrease > 75%	UO < .3ml/kg/h x 24 hr or Anuria x 12 hrs	
Loss	Persistent ARF** = complete loss of renal function > 4 weeks		High Specificity
ESRD	End Stage Renal Disease		

or urine output criteria to classify patients into three severity categories: Risk Injury and Failure; and two additional outcome categories: Loss and ESRD.

RIFLE Stratification in Patients Treated with CRRT



Conclusions:

An increased treatment dose from 20 ml/h/kg to 35 ml/h/kg significantly improved survival.

A delivery of 45ml/kg/hr did not result in further benefit in terms of survival, but in the septic patient an improvement was observed.

Our data suggest an early initiation of treatment and a minimum dose delivery of 35 ml/h/kg (ex. 70 kg patient = 2450 ml/h) improve patient survival rate.

Effects of different doses in CVVH on outcome of ARF - Ronco & Bellomo study. Lancet . july 00

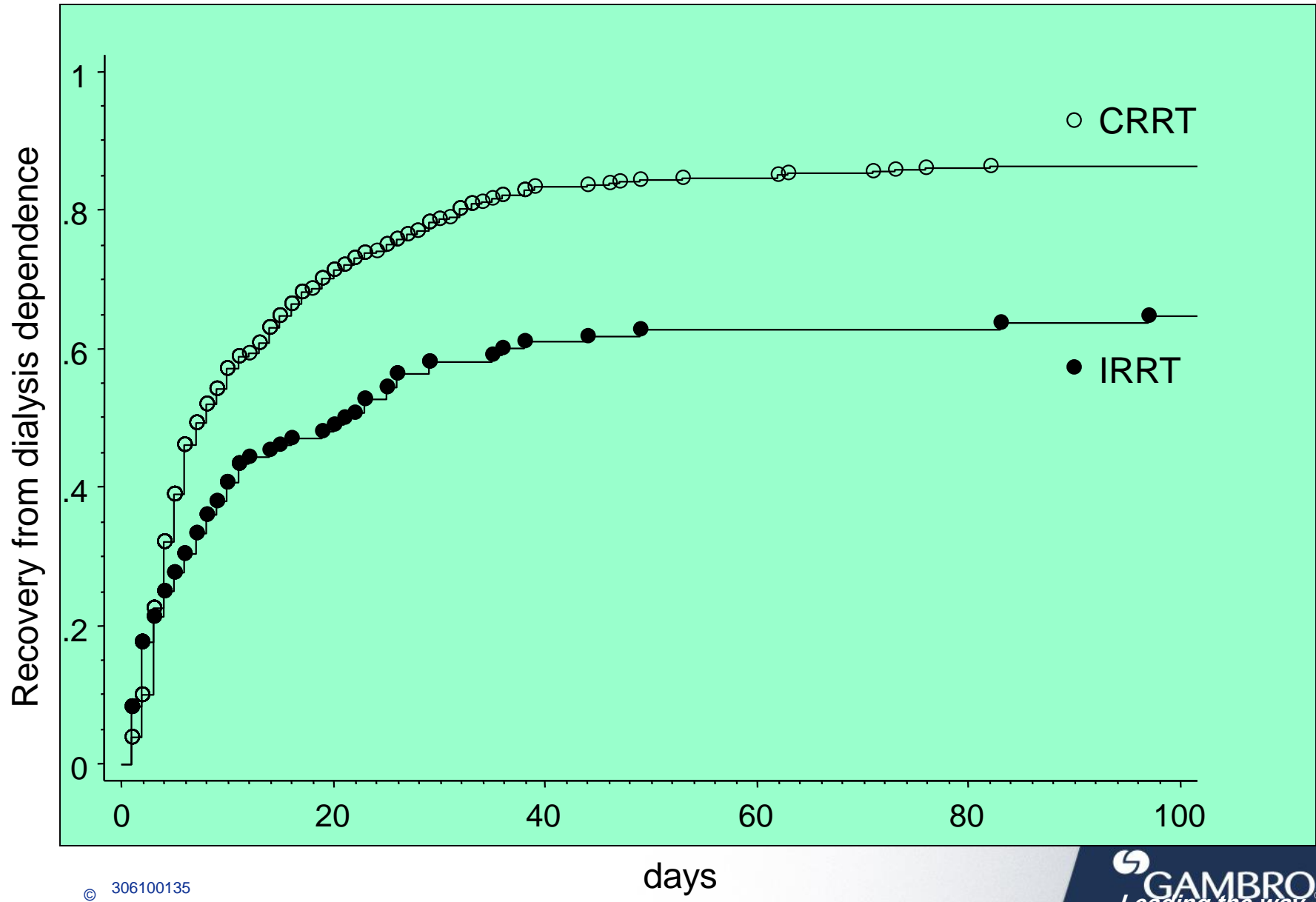
Renal Recovery?

CRRT does affect resumption of function.

By avoiding hypotensive episodes,
the risk of further kidney damage is
reduced and the chance for renal
recovery is enhanced

Recovery from Dialysis Dependence: BEST Kidney Data

Manuscript under review



CRRT vs. IHD in Renal Recovery

Recent studies suggest that CRRT is superior to IHD with respect to recovery of renal function

Implications go far beyond just “hard” endpoint of renal recovery

- Need for chronic dialysis impairs quality of life
- If length of stay (LOS) in ICU can be reduced this will have a major impact on hospital budget
- Patients dependent on chronic dialysis will consume significant health care resources and have an impact on the community health care budget

Questions?